

INTERNATIONAL TECHNOLOGY TRANSFER AND THE AFRICAN FARMER:
THEORY AND PRACTICE

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It is likely that Sub-Saharan Africa will experience chronic food deficits well into the future and thus require food imports on a concessional basis for many years to come. This judgement is shared by IFPRI, the World Bank, and the FAO.

- USDA, 1984

I. INTRODUCTION

Africa is now at the center of the world food and hunger discussions because there is growing support for the view that the basic problem - the food production gap - has been building up for several decades and it will require a minimum of 10-15 years to solve it (Eicher, 1982). The selection of Food Security in Africa as the theme for a meeting of Deans of Faculties of Agriculture is timely because this is the tenth anniversary of the 1974 World Food Conference in Rome, a ministerial-level meeting called to deal with what was perceived to be a world food crisis. Although the world food crisis vanished a few years after the Rome conference, the food production crisis in Africa is real. Moreover, Africa's food production problem will not vanish through short term responses such as increasing aid, policy dialogues and the preparation of food strategy statements.

Concept of Food Security

The concept of food security gained international attention during the Rome conference; it dominated the entire meeting. Today food security - like farming systems research - is a household word in the development literature and in policy dialogues between donors and aid recipients. Food security can be broadly defined as "the ability of food-deficit countries or regions or households within these countries to meet target levels of consumption on a yearly basis" (Siamwalla & Valdes, 1984). There are four components (cornerstones) of a national strategy to achieve food security:

- efficient growth of food and agricultural production
- employment and income-generating opportunities to enable rural and urban people to purchase an improved diet
- access to food to ensure that the entire population can satisfy subsistence food requirements
- adequate grain reserves, and/or reliable trading agreements for protection against bad harvests, national disasters and uncertain world food supplies^{1/}.

II. PLAN OF PAPER

Because Africa is so large and its agriculture is so complex and diversified, I shall focus on one of the four components - increasing food production - of a national strategy to increase food security. I begin by examining the changing perspectives on global food security since the 1974 Rome Conference and then analyze Africa's current food security problems within the global context. The core of my paper is devoted to an analysis of the role of technology transfer in increasing food production and food security. Technology transfer is an appealing and emotional concept; it forms a central link in the global agricultural research system and it is a key component of strategies to increase agricultural production in Africa. Moreover, technology transfer is an article of faith among most international food agencies and the 35 donors supporting the Consultative Group for International Agricultural Research (CGIAR), the Washington based organization that provides policy direction for the 13 International Agricultural Research Centers (IARCs). Through case studies, I shall examine technology transfer in theory and practice. I conclude by discussing five major issues for further debate and analysis by African states, international and regional research institutes and donors.

^{1/} These objectives are widely endorsed with varying degrees of emphasis by Timmer, et al (1983); Timmer (1984); Siamwalla and Valdes (1984); World Food Council (1984) and the FAO (1983).

III. GLOBAL FOOD SECURITY: 1974-84

The 1974 World Food Conference was called because of the immediate threat of famine in the Indian sub-continent and the Sahelian region in West Africa, the drawdown of world food reserves to their lowest levels in 25 years and a dramatic increase in food prices over the 1972-74 period (WFC, 1984). The overriding assumption in the minds of many conference delegates was that real food prices would continue to rise in the 1970s and that mass starvation was a distinct possibility because of rapid population growth and the lack of global reserves.

The Rome answer to lagging food production was to urge food-deficit countries to mobilize political support for the food and agriculture sectors, to set up the International Fund for Agricultural Development (IFAD) to attract more aid for agriculture and to expand the global agricultural research system. The conference adopted an annual target of a 4 percent growth rate of food production in Third World countries. Since there was reasonable confidence about the technical means to increase production, it was assumed that "the worst aspects of hunger could be eradicated in a decade and the threat of starvation could be virtually eliminated" (WFC, 1984, p.1).

Looking back over the past ten years, some important lessons have been learned about nature of food and hunger problems, and the perils of forecasting:

- The major assumption of the 1974 conference - the world was entering a period of rising real food prices - was proved to be ill-founded. Cereal production recovered slowly in the late 1970s and the record world harvests of 1981 and 1982 depressed the real market prices for cereals to their lowest levels in 30 years. Today, there is ample food at the global level, depressed grain prices and unmarketable production in North America and the European Community.
- Global food production has made major strides in the past decade: the world is feeding nearly 1 billion more people in 1984 than in 1974 and there is ample food produced globally for all the world's people.

- There is now a better scientific understanding of the nature and extent of malnutrition. The hunger problem is no longer perceived to be a lack of protein but primarily a lack of calories (undernourishment) which, in turn, is closely linked to poverty. Most diets will meet protein requirements as long as enough calories are consumed (Payne, 1978).
- The emphasis on nutrition has now shifted from a concern for protein to direct measures to assist vulnerable groups and measures to increase employment and income earning opportunities so that people can produce more of their own calories or purchase more calories in the market.
- There is no agreement on the number of poor and undernourished in the world. The estimates of three leading food organizations are as follows: 450 million, FAO; 840 million, IFPRI; and 1.3 billion, World Bank (WFC, 1984, p.4). Whichever estimate one accepts, it is staggering when compared with the 1974 Conference theme that hunger could be eliminated within a decade.
- Asia has made rapid strides in increasing food production since 1974. Even though 2/3 of the world's poor and undernourished are in Asia, international concern for food and hunger problems has slowly shifted from Asia to Africa since the Rome conference (WFC, 1984).

In summary, concern over a world food shortage and rising real prices of food vanished several years ago. The major food issues today are world food surpluses, hundreds of millions of poor and undernourished and Africa's chronic food deficits.

IV. AFRICA'S FOOD SITUATION IN THE GLOBAL CONTEXT

Despite enormous physical potential to produce food and record levels of foreign aid, Africa has slowly lost its ability to feed itself. Moreover, Africa's population growth rate is expected to remain high - around 3% - for the rest of the century. With little political support for family planning, Africa's "population treadmill" will grind out several hundred million more people by the close of this century. The highlights of Africa's current food situation are:

- Per capita food production has been declining for about 15 years.

- Africa's annual population growth rate of around 3% will lead to a doubling of population within the next 20-25 years. In a few countries with growth rates approaching 4 percent (e.g. Kenya and Zimbabwe), the population doubling time will be 17 to 20 years.
- Foreign exchange shortages - although small in contrast to financial problems in Latin America - are a major constraint on the ability of African states to import food on commercial terms.
- The combination of rapid population growth, declining per capita food production and foreign exchange constraints, leads to a simple conclusion - many African states will require food imports on a concessional basis well into the future (USDA, 1984).
- The FAO identified 24 African countries with food emergencies in 1983/84. This group had total cereal import requirements of 5.3 million metric tons. Because of foreign exchange constraints, the 24 countries will import about 2 million tons on commercial terms, leaving 3.3 million tons that will depend on food aid.
- Nigeria and South Africa are key countries in Africa's food equation. Nigeria will increase its commercial food imports by 20 percent this year. South Africa, historically a major grain exporter (South Africa exported nearly 5 million tons of grain in 1982) was forced to curtail grain exports this year; it will import 3 million tons of grain or more during 1984/85. South Africa is now a net food importer for the first time since World War II.

To deal with its food crisis, African states have requested increased aid and donors have responded dramatically over the past decade to the point where per capita aid levels are, by a large margin, the highest in the world (Eicher, 1983 and Lele, 1983). But in the past few years, aid flows have leveled off in real terms. Moreover, there is growing concern among donors that increased attention should be devoted to macro policies for food and agriculture. For example, the World Food Council has urged African states to prepare food strategies. Today, 32 of the 50 countries implementing national food strategies in the world are African nations. Donors are also pressing for policy dialogue and policy reform as a precondition for aid. For example, Edgard Pisani, EEC's Commission for Development, recently stated that because the project approach was failing

to increase food production in Africa "from now on" the EEC is "going to finance policies - hence the term policy dialogue" (1984, p.68).^{1/}

V. INCREASING FOOD PRODUCTION IN AFRICA: THE ROLE OF TECHNOLOGY TRANSFER IN THEORY AND PRACTICE

Background

By year 2000 there will be few areas in most African states where agricultural production can be increased by expanding the area under cultivation. As a result, the focus of agricultural research and extension programs will have to shift to yield-increasing-biological and chemical technology. Research and policy attention should also focus on reducing the dependency on rainfall through an evolutionary process of bringing more land under irrigation over a time-span of many decades. In short, African agriculture is at a crossroads in the transition from land extensive (surplus) farming systems to a science-based intensification of agricultural production. There is growing agreement among technical scientists that although the:

Green Revolution successes of IRRI and CIMMYT provided dramatic support for the establishment of additional IARCs we are now faced with a much slower and more laborious process: of pushing up yields, step by step, a little at a time. (Simmonds, 1984, p.6)

In my judgement, expanding agricultural production is the overarching issue facing agricultural policy makers, planners and educators for the rest of this century. I shall now discuss the three stages of technology transfer and the potential role of technology transfer in helping increase food production over the next 10-15 years.^{2/}

^{1/} For similar views on the need for agricultural policy reforms see the Berg report (World Bank, 1981); the Nordic View (Nordic Group, 1984); the U.S. View (Schultz, 1984).

^{2/} I have drawn on Eicher & Baker (1982) and Eicher (1983) for this section.

Technology Transfer in Theory

The rationale for technology transfer is based on two simple premises. First, because of scarce resources, it is impossible to fund a research effort on every commodity in every country. Second, a "critical mass" of scientists is needed to produce new knowledge through basic - and to a lesser degree - applied research. This critical mass concept was central in the decision of the British colonial service to launch the Empire Cotton Growing Association in 1921. Cotton researchers were concentrated in key countries in Africa - and in other continents - and linked through a global cotton research network (Anthony et al 1979). Later, global and regional commodity research networks (e.g. West African Cocoa Research Institute) were developed by the French and British in Africa (Eicher, 1967). By focusing on a commodity or a problem that was common in many countries, the colonial governments were able to finance a "critical mass of scientists" in a single location. In theory, technology transfer can play a crucial role in diffusing the results of research produced in "critical mass" research centers. Because many African countries have small pools of trained manpower (Table 1) they, by necessity, must rely heavily on imported technology. Finally, because agricultural production is a location specific process there is a need for adaptive research to adapt technology to mega environments.

Stages of Technology Transfer

Hayemi and Ruttan, have classified technology transfer according to three interrelated stages:

- Material (direct) transfer - direct transfer of materials such as seeds, machinery, pesticides, cattle and fertilizer.^{1/} Local adaptive research (e.g. fertilizer trials (B.Sc. and M.Sc.)) is often required to develop location specific recommendations for the use of the imported technology.

^{1/} The idea of direct technology transfer gained instant credibility among development practitioners in the late 1940s when the U.S. Point IV Program was established and "agricultural extension advisors swarmed over the developing world in the 1950s, bringing US and European 'know how' to the farmers of the tropics." (Evenson, 1984).

- Design Transfer - transfer of designs, blueprints, formulas, books, computer software, etc. Local training enables scientists to carry out adaptive research (e.g. FSR) to more effectively use the imported technology.
- Capacity Transfer - investment to Ph.D. level training to create an indigenous capacity to provide scientific and technical leadership in the public and private sectors for national agricultural development. Investment in libraries, laboratories, computers and equipment is necessary to attract and retain scientists to carry out basic and applied research. Due to the long-term pay off to these investments, consistent funding is needed for 20-30 years to build this local capacity.

Hayemi & Ruttan, 1976, p.175.

I shall now analyze technology transfer in practice in Africa by examining crop and animal improvement programs in historical and contemporary perspective.

Technology Transfer in Practice

Historical Experience

The role of international technology transfer is illustrated by the history of crop improvement research on three crops - oil palm, cotton and maize - in Africa over a period of many decades. The development of hybrid oil palms represented a spectacular Green Revolution-type of breakthrough in Africa. The demand for oil palm research is directly linked to Sir William Lever's decision to establish plantations in the Congo in the 1920s after Lord Lugard, the Governor of Nigeria, rejected his request to establish them in Nigeria. In 1926, the Belgian colonial office set up an oil palm research station in the Congo to carry out basic and applied research to assist plantation development. Over a period of several decades, hybrid palms were developed by crossing local varieties with plant material from Indonesia. Nigeria's oil palm station was established in 1939 and it drew heavily on plant material from the Congo (Hartley, 1958). Hybrid palms were developed for local conditions in Nigeria and they outyielded wild palms by 500 to 700 percent under smallholder conditions (Eicher, 1967). The emergence of the Ivory Coast as the leading palm producer in West Africa in the 1970s

is partially a function of the improved plant material supplied by the IRHO research network.

Cotton research in Africa is an accumulation of eight decades of experience starting with Uganda's importation of Upland types from the United States in 1904. Several decades later, the Samaru station in northern Nigeria imported the Allen variety of Upland cotton and adapted it to local conditions. The Empire Cotton Growing Corporation was started by the British in 1921 and it became the forerunner of the concept of research networks that were subsequently launched by the Belgian and French colonial governments and later by the IARCs beginning in the 1960s (Anthony, et al 1979). Under the leadership of French cotton researchers and the French Cotton Development Organization - CFDT - cotton has become an important crop in the Ivory Coast, Mali and Upper Volta.

Maize is the dominant staple in many countries in Eastern and Southern Africa. Two examples from Zimbabwe (formerly Southern Rhodesia) and Kenya illustrate the time and the continuity of investigation to develop high-yielding hybrid varieties and the differing roles that material (direct) technology transfer played in the breeding programs in each country. In 1932, research on hybrid maize was launched in Southern Rhodesia by H. C. Arnold; in 1938, A.G.R. Rattray took over the research program and continued it for 30 years until he retired from government service in 1968.^{1/} In 1949, seventeen years after hybrid maize research was initiated, the first hybrid, SR-1, was released to farmers and Southern Rhodesia became the first country after the United States to produce hybrid

^{1/} A.G.R. Rattray is still an active maize breeder at a private research station (Rattray Arnold Research Station) financed by the Zimbabwe Seed Cooperative outside Harare. Rattray's 46 years of hybrid maize breeding is probably unique among maize breeders anywhere in the world. In terms of continuity, four research officers have directed Zimbabwe's maize programs over a period spanning 54 years: H.C. Arnold (1932-38); A.G.R. Rattray (1938-68); P. Nelson (1965-70) and R. Oliver (1970-1984).

corn commercially.^{1/} But the big breakthrough came eleven years later in 1960 when a high yielding, long season (150 day) white dent - SR 52 - was released. Subsequently, SR 52 seed was sold and is still being sold to neighboring countries today. Moreover, SR 52 is still the dominant variety used by commercial farmers^{2/} in Zimbabwe 24 years after its release in 1960. SR 52 is undoubtedly the Green Revolution success story in Southern Africa. But it is significant to note that imported germplasm has not played a significant role in Zimbabwe's maize research program over the past fifty years. Most hybrids in Zimbabwe are derived from two local varieties known as Southern Cross and Salisbury White. These varieties had been grown for a long time and continually mass selected in the Rhodesian Highlands. SR 52 is a single cross hybrid and its two parental lines were developed independently by two researchers H.C. Arnold and A. Rattray (Gelaw, 1984).

In Kenya, research on hybrid maize began in the mid-1950s at the urging of large-scale European farmers. The following synopsis indicates that material (direct) technology transfer played a central role in hybrid development:

1/ Surprisingly there was almost no intellectual exchange or exchange of plant material between hybrid maize breeders in the United States and those in Southern Rhodesia during the 1930s and 1940s. Southern Rhodesia encouraged its scientists to travel and interact with scientists in the other parts of the world beginning in the late 1940s and early 1950s. (Rattray, 1984)

2/ An early (130 day) maize hybrid - R201 - is now widely used by communal farmers (small-holders); it has been the most important variety in terms of area planted in Zimbabwe since around 1980. Seed packs of treated seed are available in retail seed shops and co-ops throughout the country in 2, 5, 10, 25 and 50 kg units in order to encourage farms of any size to plant hybrids. Hybrid seed sales have shot up 60 percent since independence in 1980 as communal farmers have eagerly adopted hybrids. In short, hybrid maize is a "self-spreading" innovation in Zimbabwe. Historically, communal farmers never sold more than 80,000 tons of maize until 1981. In 1981, this figure shot up to 324,000 tons and 400,000 tons in 1982. Now the challenge is to increase small holder yields of one ton compared with roughly four tons per hectare on commercial farms.

The Kenya government, with Rockefeller Foundation support, hired Michael Harrison as a maize breeder to work at Kitale Research Station. His early work with local varieties had resulted in only mixed success in increasing yields. Then following his AID and Rockefeller-sponsored trip to Mexico to collect new maize breeding lines, Harrison's luck changed. In experiments involving some 200 lines, he crossed an Ecuadorian line - Ecuador 573 - with the best local variety, Kitale Synthetic II and the resulting hybrid, H611, produced a remarkable 40% increase in yield and proved appropriate to the high potential areas of Kenya, with their fertile soils, abundant rainfall and moderate temperatures. (AID, 1983a, pp.1-2).

The time period for the development of the H611 was roughly a decade - 1955 to 1964. Later research produced improved hybrids and composites tailored to different elevations. Kenya's hybrid maize research program is regarded as the food crop success story in Eastern Africa. Although the original pressure for hybrid research came from large farmers, the results have benefitted both smallholders and large farmers.

In West Africa, maize is a minor crop relative to millet and sorghum - the staple foods in rural areas and rice and wheat in the cities. Smallholder maize yields are low - 200 and 900 kg/ha - compared with maximum yields of 8 tons/ha on research stations (Matlon, 1983). For reasons that are unclear, CIMMYT, ITTA, IRAT and national research and extension services have been ineffective in producing maize varieties that are "self spreading" like those in Zimbabwe and Kenya. Perhaps one reason is that a sustained maize breeding program has not been carried out in West Africa over a period of several decades. Plant breeding is partially an art; it takes an unusual person to accept that fact that a minimum of a decade of work will probably be needed before a significant payoff is forthcoming.

To summarize, these case studies provide two insights into the role of technology transfer in crop improvement programs:

- Material (direct) technology transfer of genetic material has played a central role in oil palm and cotton improvement programs, especially when viewed over a period of several decades. The record on maize is mixed.

In Zimbabwe, local breeders developed hybrid maize over a period of several decades by the mass selection of two (local) open pollinated varieties. In Kenya, a wide range of Latin American plant material was crossed with local material. In West Africa, there has been little improvement in maize technical packages for decades.

- Crop improvement programs should be conceptualized in time-scales of decades rather than years.

Technology Transfer: Contemporary Experience

In this analysis of technology transfer, I shall concentrate on food crops and livestock improvement programs. Four international regional institutes dominate food crop research in Africa: IRAT, IITA, ICRISAT and WARDA. Since IRAT's experience in developing new food crop technologies appropriate to the needs of smallholders in West Africa has been recently analyzed by Vallaeys and Silvestre, (1983),^{1/} I shall concentrate on the three institutes in the CGIAR system, IITA, ICRISAT and WARDA.

The International Institute for Tropical Agriculture (IITA) was established in 1967 near Ibadan and it has been beset with problems since the early debate over whether it should be located in the Savannah zone in the Middle Belt of Nigeria or near Ibadan - a transition zone between the humid tropical forest and the savannah. Some of the considerations that led to the Ibadan location included its proximity to the University of Ibadan, and reliable schooling and medical facilities.

Since IITA was opened a few months after IRRI had released its high-yielding rice variety - IR-8 - after only 6 years of research (1960-66), it is understandable that some of the IITA scientists were optimistic about bringing about a Green Revolution in Africa in a relatively short period of time. Eight years after IITA was launched, it appeared that IITA was on the verge of some breakthroughs. In 1975, D.J. Greenland, Director of Research, IITA, published an article in the prestigious Science magazine on

^{1/} The authors report that IRAT has not produced any breakthroughs in food crop research in West Africa.

bringing the Green Revolution to shifting cultivators. Greenland reported on promising IITA research on zero tillage and legumes with nitrogen fixing rhizobia. He contended that although the ingredients of a farming system for the small farmer in the lowland humid tropics have not been put together and tested as a whole,

"fortunately this is not an essential preliminary to their use. All are compatible with existing systems of shifting cultivation and introduction of any one or more of these into the system should lead to immediate though not always dramatic improvements in production"...we can expect higher and more stable production to come quietly but quickly to small farmers throughout the world and have a more lasting effect than the first phase of the Green Revolution" (Greenland, 1975, p.844).

Three years later, however, the TAC Review Mission observed that IITA was experiencing problems in recruiting and retaining a core of senior scientists. It further noted that because IITA was facing some of "the broadest, most complex and challenging" problems of the IARCs, it should consolidate its activities and leave a number of activities to be carried out by national research programs (TAC, 1978).

After years of laudable effort by many IITA scientists and cumulative core operating and capital expenditures of around \$170 million (1965-1983), it seems fair to ask whether IITA has delivered on its research mandate. IITA's research on high yielding varieties of cassava combining resistance to bacterial blight disease and African mosaic virus has been outstanding and its research on streak resistance maize germplasm is an important contribution. IITA's research on early cowpea varieties (55 to 60 day) is encouraging but the varieties are not ready for release to farmers. However, the IITA is promoting tie ridging as a new concept even though it was promoted by colonial research services back in the 1940s. Although IITA scientists have concentrated on developing improved farming systems in the humid and sub-humid tropics since IITA was established, no breakthroughs are on the horizon. IITA scientists qualify their progress by noting that "no till" farming technology "appears to be a viable alternative to the current bush fallow system" (Singh, 1984, p.4). A 1983 external review panel praised

Director-General Hartmans and his staff for their "significant achievements" but cautioned IITA about getting involved in too many agricultural development projects because there is a danger that its basic mission-agricultural research - will suffer (TAC, 1983, p.18). Although the IITA has been rejuvenated under the dynamic leadership of Director-General Hartmans, the verdict is still out on whether IITA can achieve the big breakthroughs that have been promised for almost two decades.^{1/}

I shall now examine sorghum and millet because these crops constitute about 2/3 of the total cultivated area in the West African Semi-Arid Tropics in 1980 and they are important in the Sudan and in Southern Africa. I shall concentrate on ICRISAT's experience in West Africa over the past decade and its current effort to launch a long term research program in the SADCC states of Southern Africa. Historically, two major research strategies have been pursued to increase sorghum and millet yields and yield stability in West Africa. The first strategy - improving local varieties through mass selection - was pursued for several decades by colonial researchers at the Samaru research station in Northern Nigeria and the Bambey Station, in Senegal.^{2/} Because this strategy did not produce high yielding varieties, it is understandable that, in the aftermath of the 1968-74 Sahelian drought, ICRISAT was invited to develop a sorghum and millet improvement program for West Africa. ICRISAT's West African program was launched in mid 1975 by posting scientists in Upper Volta, Senegal and Nigeria and later in Niger and Mali. ICRISAT pursued the first stage of technology transfer (material transfer) and imported improved varieties^{3/} because it was assumed that imported material would diversify the genetic stock in West Africa and speed up the process of developing high yielding varieties appropriate to the needs of smallholders. I recall my October 1975 conversation

^{1/} For an internal view of IITA's achievements see Ter Kuile (1983) and Singh (1984).

^{2/} Millet research was launched at Bambey, Senegal in 1931.

^{3/} The material was mainly of Indian, Nigerian and Ugandan origin.

with C.M. Pattanayak, ICRISAT's Team Leader at the research station outside Bobo Dioulasso in southern Upper Volta. At that time, Dr. Pattanayak was optimistic that ICRISAT's direct transfer strategy could develop yielding varieties for release to farmers in 4 to 5 years. But eight years after ICRISAT launched its West Africa program, Pattanayak reported that "variations in rainfall, soils, and farming conditions" probably explain why the direct transfer of high yielding sorghum and millet varieties to West Africa has been "relatively unsuccessful at the farmers' level" (1983, p.14). An ICRISAT agricultural economist added that "the improved sorghum and millet varieties which have experienced relatively more success ...are improved locals derived from West African genetic stock" (Matlon, 1983, p.35). ICRISAT has also learned that the dispersion of 22 scientists over five countries in West Africa presented administrative and management problems and made it difficult for the dispersed breeders and agronomists to receive adequate inputs from other disciplines (ICRISAT, 1983, p.20).

Drawing on its disappointing experience with direct technology transfer and the dispersion of its scientists throughout West Africa, ICRISAT developed a new research strategy for Africa which deemphasizes the direct transfer of technology, promises of short term breakthroughs and dispersion of staff (ICRISAT, 1979 and 1983). The new strategy is cast in a 20 to 25 year time frame and it involves a concentration of researchers at three to four Regional Research Centers in Africa. ICRISAT is implementing its new Regional strategy by developing a Sahelian Center about 45 km. outside of Niamey, Niger. About a dozen senior scientific staff will be working in three interdisciplinary groups at the Sahelian Center on millet, groundnut and farming systems. ICRISAT's sorghum scientists are being regrouped and posted in two locations - Ahmadu Bello University in northern Nigeria and in Upper Volta.

Multi-disciplinary teams at ICRISAT's regional centers will carry out basic and applied research to develop varieties that are resistant to disease and insects and have agronomic superiority, yield stability and food quality traits preferred by local

consumers. Plant breeders at the Regional Centers will carry out a dual strategy of importing plant material from throughout the world, screening local varieties and crossing local with imported varieties. The regional team will carry out multilocal variety trials in cooperation with scientists in national programs. The agronomist from the Regional Center will work with local FSR teams in carrying out on-farm trials of promising varieties and technical packages.

Turning to ICRISAT's work in Southern Africa, in 1980, the nine member countries of the Southern African Development Coordination Council (SADCC), invited ICRISAT to set up a major Research Center in the Region, embracing the five crops in its mandate. After careful deliberation, ICRISAT decided to concentrate on three crops - sorghum, millet and groundnuts - that historically had been neglected by the British, Portuguese, and German colonial research services. Drawing on its West African experience, ICRISAT is currently in the process of establishing, on behalf of SADCC, a Sorghum and Millet Research Center for Southern Africa at the Matopos research station outside Bulawayo in southern Zimbabwe. Eight ICRISAT scientists at the Matopos Station will develop and implement a long term (20 to 25 year) research program in close cooperation with scientists in national research services - the main recipients of ICRISAT's regional program in Southern Africa. To summarize, ICRISAT has learned that developing a research and training program appropriate to the diverse agro ecological environments, and the current stage of Africa's absorptive capacity, is a long and painful process. The SADCC states stand to benefit from ICRISAT's experience in learning how to get its feet on the ground in West Africa over the past decade.

Although rice is a minor crop in Africa (3 percent of the world's acreage under cultivation), it is an important crop in West Africa where urban consumer preferences are rapidly shifting from millet, sorghum, cassava and yams to rice and wheat. In fact, West Africa has been importing around a million tons of rice per year since the mid 1970s. In 1971, the West African Rice Research Institute at Rokupr, Sierra Leone was reconstituted as the West

African Rice Research Association (WARDA). WARDA's headquarters was established in Monrovia, Liberia and it was given a mandate to carry out training programs, feasibility studies and variety trials in cooperation with national programs in 15 member states. When WARDA was established, it was assumed that IRRI's high yielding (irrigated) rice varieties could be imported by IITA and WARDA and screened through variety trials carried out by WARDA in member states. It was also assumed that IRAT's research on rainfed rice at Bouake, Ivory Coast would produce improved varieties for WARDA and national programs. But, after seven years of trials of 4000 imported mangrove swamp rice varieties, WARDA found that only two yielded as well as the best local varieties.^{1/} Although some of IRRI's irrigated rice varieties performed well under farm level conditions in West Africa, rainfed rice accounts for 95 percent and irrigated rice only 5 percent of the area under rice cultivation in West Africa. IRRI has recently stepped up research on dryland rice because "two-thirds of the 12.7 million ha of rice land in Latin America and Africa is dryland" (IRRI, 1982, p.65).^{2/}

Because of its disappointing experience with the direct importation of new rice varieties from IRRI, WARDA launched Special Research Projects in the mid-1970s in Liberia, Sierra Leone, Mali, Senegal and the Ivory Coast. But WARDA's Research Department has been criticized for keeping too many research scientists at its Monrovia headquarters rather than in the countries where Special Research Projects are being carried out. Robert Chandler, former Director-General of IRRI, noted: "I have not yet seen a good research program administered by a central urban office unless capable scientists were stationed at the locations where the field and laboratory work was taking place" (Chandler, 1976). Although WARDA receives high praise for its training program, its research

1/ Dunstan Spencer, until recently the Director of WARDA's Development Department, reported this result at a 1983 conference at Victoria Falls, Zimbabwe.

2/ Dryland research, includes varieties grown under both rainfed and upland farming conditions.

program is under heavy attack^{1/} and financial support from member states has been flagging in recent years. D.J. Greenland, Deputy Director-General of IRRI (and former Director of Research at IITA), recently reflected on IRRI's assumption of the early 1970s that irrigated varieties could be directly transferred from Asia to Africa and adapted for rainfed farming as "a little naive" (Greenland, 1983). In summary, the direct technology transfer assumption of the early 1970s has proven to be a heavy burden for WARDA to bear over the past decade.

Livestock is an important enterprise in Mauritania, Mali, Upper Volta, Niger, Ethiopia, Tanzania, Botswana and Zimbabwe. But livestock improvement has proven to be a difficult problem area for both African states and donors. As a result, many studies reporting the failure of livestock projects are never published. For example, the World Bank has kept Stephen Sandford's consultant report on the World Bank's experience with livestock projects in dry tropical Africa "under wraps" since it was completed three years ago (Sandford, 1981). A few months later, the Berg Report on Africa did not devote a single paragraph to the Bank's experience with livestock, even though it was critical of large-scale irrigation projects of several African states (World Bank, 1981).

Fortunately, a few studies of livestock interventions are being published, including an assessment of a long term project to help Maasai pastoralists in Tanzania enter the market economy. The following excerpts from "A New Reality: Western Technology Faces Pastoralism in the Maasai Project" by Moris and Hatfield, (1982) illustrate some of the difficulties in transferring technology (e.g. U.S. range management practices) to Tanzania with the help of a technical assistance team over a decade:

- "The Maasai Livestock and Range Development Project arose from a marriage of national and international concerns (p.43)...it began with what now seems naive assumptions about the capabilities of western technologies to solve Third World problems" (p.60).

^{1/} See Chandler (1976); TAC (1979) and AID (1983).

- "In the early phases, technical specialists in Maasailand viewed technology transfer mainly as adjusting tried and true solutions to the local scene" (p.45).
- "The developers saw no problem in replacing the broad Tanzanian goal of development of the Maasai with a more easily measured proxy objective: achievement of high off take" (p.50).
- "The difficulties that the Maasai Project experienced were only partly derived from the cultural features of the Maasai people. To a much greater extent they represented intrinsic weaknesses of range management approaches, which are based upon six premises appropriate only to the Western U.S. cultural setting" (p.46).
- "By the end of 1978, the team consisted of 10 expatriate specialists, none of whom had been involved in the early stages of project implementation, nor its planning" (p.44).
- "In its day, the Maasai project was thought to be a pioneer design for modernizing pastoral peoples (p.60). Ten years after the establishment of the Maasai Project, its goals had not been realized" (p.44)".

Moris and Hatfield, 1982.

We can gain a broader perspective on livestock change by examining the experience of the International Livestock Center for Africa (ILCA). ILCA is now 10 years old and it seems fair to ask what it has accomplished to date. A review of ILCA's record begins by examining a 1973 task force report that played a critical role in the history of the establishment of ILCA in 1974. The task force of four livestock specialists was commissioned by the CGIAR to examine the state of the art of livestock research in Africa and to suggest an agenda for ILCA. The task force report is commonly known as the Tribe report.^{1/} The following excerpts from the Tribe report indicate the spirit of optimism in 1973 about available livestock technology and the need for social scientists to assist in figuring out how to transfer and introduce this technology in the diverse pastoral systems throughout Africa:

^{1/} The team members were Barry Nestel, D.J. Pratt, M. Thorne and Derek Tribe (Chairman).

1. "The accumulated results of many years of study in a wide range of disciplines already provides a substantial foundation of technical knowledge on which to base development programmes and further scientific progress. In particular, outstanding advances have been made in animal disease control, which has received top priority in most investigational programs. Several major livestock disease (e.g. rinderpest, contagious bovine pleuropneumonia, anthrax, pasteurellosis, and the clostridial infections) are already substantially under control or, at least, are capable of control given the appropriate infrastructure and organization".
2. "The achievements of veterinary scientists have been supported by the work of geneticists, nutritionists, agronomists and rangeland ecologists. In country after country such work has clearly shown that substantial improvements in livestock production are technically possible provided that healthy, well-fed animals of superior genetic quality are grazed according to the established tenets of good pasture or rangeland management".
3. "It is only now becoming generally recognized that in order to develop African livestock industries further it is necessary to provide inputs of knowledge in economic and social sciences as well as in biological sciences. In most situations, it is problems concerned with land tenure, credit, taxation and marketing, or with human attitudes, education and behaviour that limit the application of technical knowledge, and thus the developmental process".
4. "...the immediate need is for: surveys to determine existing resources; investigations to identify the most important and sensitive social and economic constraints to livestock development; and analyses of ongoing development programs (monitoring) in order to identify the reasons for success or failure." (CGIAR, 1973, pp.18-19).

When ILCA was established, a group of social scientists was charged with carrying out socio-economic and monitoring studies in different countries of Africa. The monitoring of livestock production projects under induced change was designed to prepare a monitoring guideline and find out how to remove the socio-cultural constraints on some of the technology that was assumed to be available for extension services and pastoralists. But after a few years:

"Monitoring subsequently became a rather unpopular term and activity, not because it was not necessary but because it was being used and carried out mostly in the project financing framework, not totally befitting the character of an international research center such as ILCA" (Anteneh, 1983, pp.7-8).

In 1982, a TAC Review Mission identified technical - not socio-economic - constraints as the critical factors limiting livestock improvement in Africa. The TAC mission was critical of ILCA's lack of progress in improving the technical research base on livestock production, its young and inexperienced staff and its over-emphasis on socio-economic baseline studies. The TAC Mission advanced 53 recommendations, including an urgent appeal to increase the scientific research capacity of ILCA by hiring six senior scientists to deal with problems such as animal nutrition, health, forage legumes, etc. (TAC, 1982). ILCA's new Director-General has taken aggressive steps to implement the 53 recommendations and to build up ILCA's senior scientific staff. Since ILCA is 10 years, it is clear that the pay off to investments will likely be forthcoming during ILCA's second decade. ILCA's first decade - like ICRISAT's first decade - has been spent in getting its feet on the ground in Africa.

Forestry development in the Sahelian region of West Africa provides an example of the direct transfer of technology - exotic species of trees - to increase fuel wood production. Over the past seven years, \$160 million of forestry projects have been launched in the Sahel. A landmark paper by Taylor and Soumare (1983) reviews some of the problems in developing cost effective fuel wood production projects in the Sahel:

1. In Senegal, the exotic species, eucalyptus camaldulensis, planted at a cost of \$800 +/-ha, is estimated to be producing 1.5 m³/ha/ya while the native acacia seyal forest, bulldozed at high cost to plant eucalyptus, is producing between 0.8 m³ and 3.2 m³/ha/year with an average annual production of between 1-1.5 m³/ha/year under no management.

2. In some cases, adequate market studies have not preceded plantation establishment. For example, 17,000 steres (8,500 m³), of wood are rotting by the roadside 80 km from Bobo Dioulasso in southern Upper Volta because of the lack of a market. Fuel wood traders are unwilling to purchase and transport it to markets even on highly concessional terms.

3. In Niger, an irrigated fuel wood plantation developed with World Bank funding will be discontinued because it is too costly to irrigate the plantation.

Taylor and Soumare conclude their bleak assessment of "crash fuel-wood projects" by noting that, with the notable exception of Senegal, the forestry research infrastructure in place in the Sahel "is so small as to be virtually nonexistent". The authors are of the conviction that "Forestry research is an essential prerequisite to more effective project interventions and it must be given the attention it deserves with priority attention to the building of national research capability" (Taylor and Soumare, 1982, p.32).

Technology Transfer and African Agriculture: Summing Up

The theoretical case for technology transfer is straightforward. There is a proven payoff to scientists working in research teams, task forces and institutes. It is assumed that the output of these research groups - improved technology - can be transferred through the public and private sectors to clients in other geographical settings. Because of the small pools of trained agricultural scientists in most African countries (Annex Table 1), the concept of importing technology is an attractive proposition in Africa.

The starting point in the analysis of technology transfer in practice is to define the concept. Hayemi and Ruttan's three stage classification of technology transfer: material (direct), design and capacity transfer suggests a continuum of interrelated stages. Micro computers illustrate the transfer process. In the first stage, micro computers can be transferred (material transfer) the Third World. In the design stage, local programmers can be trained

to use the micro computers and software programs can be revised and adapted to local conditions. In the capacity transfer stage, a country develops the scientific capacity to produce its own design of micro computers as Brazil is now doing. But the decision to develop indigenous scientific capacity to produce new technology is a major political issue which requires decades of consistent financial support. A Mexican agricultural economist and recent Minister of Science and Technology, Edmundo Flores, notes that:

Development may take place in a democracy or a dictatorship, under capitalism, socialism, or communism, but it cannot occur without a critical mass of specialists in science and technology. The political decision to develop science and technology requires shifting a considerable share of the government's expenditure to education and research over a long period.

- Edmundo Flores, 1983.

My analysis of technology transfer in Africa has shown that numerous plant breeders - e.g. oil palm, cotton, maize - have benefitted from imported technology over a span of many decades. But in many countries there is a gap between technology transfer in theory and in practice. I have shown that some of the IARCs operating in Africa have concentrated on transferring improved varieties (material transfer) and have spent little time on capacity transfer - i.e. helping national research services and universities develop the scientific capacity to screen, borrow and adapt technology to location specific environments. Most donors have seriously underestimated the variability in African agriculture and the indigenous science capacity required to achieve the full potential of technology transfer. The movement of donor representatives, from country to country every two to four years imposes a short term time horizon on many foreign assistance programs. Finally, the uncritical acceptance of the direct (material) transfer of technology creates the comfortable illusion among many donors that it is both possible and feasible to circumvent the long, arduous and costly process of strengthening applied and basic research capacity

within national agricultural research services and in African universities. But Africa's experience with technology transfer in 25 years of independence adds further evidence to the historical record that:

"only a country that establishes its own research capacity in agriculture can gain access to the advances in knowledge that are available to it from the global scientific community and embody that knowledge in the technology suited to its own resource and cultural endowments". (Vernon W. Ruttan, 1983,)

VI. LOOKING AHEAD: MAJOR ISSUES

Expanded food production is one of the four cornerstones of increasing food security in Africa. Sustained technological innovation is a sine qua non for shifting from a natural resource to a science-based agriculture and for increasing food production and coping with rapid population growth. In theory, technology transfer is an attractive proposition for African states. But, in practice, importing technology is critically shaped by the stage of economic history of a particular nation. At this stage of Africa's economic development, the gap between technology transfer in theory and practice is partially a function of limited administrative, managerial and indigenous scientific capacity. Unless one has a deep understanding of the complexity and diversity of African agriculture and a realistic assessment of Africa's present-day absorptive capacity, one is likely to overemphasise material (direct) technology transfer and underinvest in helping indigenous institutions expand their scientific capacity. Unfortunately, long term support for strengthening indigenous scientific capacity is receiving low priority by most African states and by donors who are, for the most part, locked into conservative three to five year project cycles.^{1/}

^{1/} For example, the IDRC of Canada and the ODA of the U.K. have a three year limit on projects. The projects are frequently renewed, of course, but the time horizon is cautious and conservative.

I shall address five major issues about science, technology and African agriculture requiring debate and further study.

A Realistic Time Frame: 1985-2000

There is a consensus emerging among scientists that agricultural development in Africa - especially in rainfed farming - is a slow, evolutionary, stepwise process. There is also a growing awareness that agricultural research is a long term process that should be conceptualized in time spans of decades rather than years. With this emerging consensus among scientists on the time frame, the next step is to gain a consensus among politicians, donors and scientists on a realistic time frame to meet Africa's food crisis. I am of the opinion that a period of 15 years (1985 to 2000) is the minimum feasible planning horizon because:

- It will take a period of five to ten years in most states to build the political support for a fundamental redirection in development strategies to give increased support to agriculture.
- It takes an average of 10 years between expenditure on agricultural research and the availability of new technology and in some cases up to 15. Major payoffs to investments in IARCs such as CIAT, ICRISAT, ILCA, will probably come in their second decade and for IITA it may reach 20 years or more.
- The lead time for the restructuring and strengthening of agrarian institutions such as credit, extension and research services must be counted in decades rather than years.
- It will take a minimum of 10 - 20 years to train and upgrade human capital for the major agricultural institutions.

International Agricultural Research Centers (IARCs)

In light of some of the problems that the IARCs have encountered in establishing relevant programs in Africa over the past 10 - 15 years, one should examine two issues: the relative emphasis that the IARCs should place on material (direct), design and capacity transfer and the mandate of the IARCs. On the first question, I believe that the IARCs should deemphasize direct technology transfer and concentrate on developing regional research networks that assist

national programs in increasing their scientific capacity to borrow technology. Regional research networks covering 6 to 10 countries can facilitate linkages and interaction between basic research, applied research and extension services.

On the issue of IARC mandates, there is a need to examine whether the CGIAR should restrict some of the IARCs to a regional mandate - i.e. concentration on food and agricultural research in Africa. A TAC team recently examined this problem and concluded that "the pursuit of exclusivity in Sub-Saharan Africa is not an evolutionary pathway that any International Center should follow. We consider that any implication of exclusivity for Sub-Saharan Africa should be removed from the IITA mandate" (TAC, 1983, p.14). But words such as evolutionary pathways can be a facile response to a problem meriting serious investigation and debate. The following discussion about IITA's mandate helps illustrate the need to examine the question of mandates for the major IARCs working in Africa. I have observed the work of IITA scientists over the past seventeen years; the mandate issue has plagued the IITA since its inception. IITA was originally given a mandate to develop improved farming systems in the humid tropics; its mandate was subsequently broadened in 1970, 1971, 1972 and 1976 to include:

- (a) worldwide responsibility covering all climatic regions for research on cowpea, soybean, pigeonpea, lima beans, yams, sweet potatoes, plantain, winged beans;
- (b) appropriate responsibilities, if asked to do so, within the African continent, for other crops (particularly those of interest in the humid tropics) for which other institutes have worldwide responsibility, such as maize, rice and cassava (TAC, 1978, p.9).

A few months ago an external review team recommended that the IITA be given global responsibility for farming systems research in the humid and sub-humid tropics (TAC, 1983, p.17). One may legitimately raise the question if IITA's FSR program has still not proven itself in West Africa, why should it be given global responsibility for the humid and sub-humid tropics.

But the mandate issue is broader than a single IARC. Who will assist in maize development in Southern Africa (CIMMYT, IITA or both); bean development in East Africa?: and who is responsible for cassava (IITA or CIAT)? These are some of the many problems facing the IARC system. These problems are difficult to resolve in the current period of tight budgets.

Strengthening National Research Services

The major lesson that one draws from Africa's experience in importing technology is that national research services should not sit back and assume that the thirteen IARCs and multinational seed chemical and machinery manufacturers will supply them with new technology that is appropriate to the needs of smallholders and pastoralists. Nor should the national research services think that donor funded FSR projects are a substitute for long term projects to strengthen the technical and administrative capacity of national research services. African states should be encouraged to grasp the nettle of the need for a stepped up and consistent national research effort as a prerequisite for tapping the regional, continental and global agricultural research system. Unless the scientific capacity of national research services is strengthened, the full potential of technology transfer from the global agricultural research system unfortunately will not be realized.^{1/}

Postgraduate Training in African Universities

• Over the past 2 - 3 years there has been a growing awareness of the need to accelerate postgraduate training in selected fields of agriculture in Africa (Eicher, 1982). There is a consensus emerging among academic staff and some donors that the time has come to shift the center of gravity of postgraduate training from Europe, North America and Australia to Africa. A similar consensus was reached about 20 years ago in Asia and Latin America.

^{1/} A micro example of underfunding of national research services in Africa surfaced during the study of the reorganization of agricultural research in Malawi. An inventory of the books in the library at the central research station (Chitedze) outside Lilongwe revealed that 95 percent of the 3000 books in the library were published before 1970 (Malawi, 1983).

In July, the results of an FAO study of agricultural training in Africa will be presented at FAO's Regional Conference in Harare. The study will show that great strides have been made in B.Sc. level training in the past 20 years except in a few critical areas such as horticulture, agricultural engineering and food science. The FAO study concludes that the next task is to improve the quality of undergraduate programs, fill some of the gaps in particular fields at the B.Sc. level and expand postgraduate training within Africa, with emphasis on the M.Sc. level training.

The USAID office for the Southern Africa Regional Program in Harare is in the early stages of developing a long term (20 to 25 year) Agricultural Training Project. The projected \$30 million project (years 1 - 5) will focus on strengthening the capacity of selected departments to offer taught M.Sc. programs in various disciplines (Blackie, 1984). It is hoped that other donors will support this effort and that a long term (20 to 25 year) plan will emerge to avoid duplication of effort - a problem endemic to veterinary medicine training facilities. Much can be learned from India's pioneering experiment in postgraduate programs and from on-going experiments in Morocco, the Cameroon and Brazil.

Implications for Donors

Donors have responded to Africa's food crisis with a doubling of aid to Africa in six years - 1975 to 1981.^{1/} However, aid has leveled off in real terms and there is growing evidence of aid fatigue because of the painfully slow progress in improving rainfed agriculture in the Sahel (Club du Sahel, 1983), the questionable value of \$2.7 billion of aid to Tanzania from 1973 to 1982, and the inability of aid to counter the declining per capita food production over the past 15 years. Although the recent drought in the Sahel, Ehtiopia and Southern Africa has brought forth renewed interest in Africa's food problems, it is common knowledge that aid is not being

^{1/} On a per capita basis, in 1981 aid flows ranged from an average of \$12 for all Third World countries, \$20 in Africa, \$42 in Mali, \$82 in Senegal and \$242 in Cape Verde (Eicher, 1983).

. absorbed with integrity in many countries and that aid coordination is simply not working. But in the final analysis, unless donors shift their emphasis from short run to long run strategic responses to deep-seated problems such as the development of indigenous scientific capacity, aid will not achieve its potential.

Table 1. Selected African Countries Classified by
Number of Agricultural Scientists and Expenditures on Agricultural
Research as a Percentage of their Agricultural GDP, 1980

Country	Research Expenditure	Agric. Scientists, 1980 (\$,000 US)	Number of As % of AG GDP	Ag Res Exp
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Expenditures over 1 percent of Agricultural GDP

Zimbabwe	10,560	201	2.42
Mali	7,354	68	1.24
Senegal	9,797	105	1.21
Kenya	24,052	400	1.19

Expenditures between 0.5 and 1 percent of Agricultural GDP

Burundi	3,610	41	0.81
Zambia	5,205	109	0.80
Ivory Coast	24,370	212	0.78
Togo	1,892	49	0.76
Malawi	4,562	276	0.75
Nigeria	134,964	1,084	0.74
Lesotho	465	14	0.60
Benin	2,405	19	0.59
Sudan	14,636	164	0.57
Chad	1,602	42	0.56

Expenditures between 0.25 and 0.49 percent of Agricultural GDP

Madagascar	4,801	68	0.39
Tanzania	7,219	256	0.35
Upper Volta ^{1/}	1,105	123	0.28

Expenditures under 0.25 percent of Agricultural GDP

Mauritania	284	8	0.22
Sierra Leone	698	35	0.21
Cameroon	3,788	106	0.20
Zaire	5,098	97	0.20
Rwanda	945	24	0.18
Ethiopia	3,400	155	0.18
Ghana	10,095	352	0.17
Liberia	394	20	0.11
Uganda	7,452	175	0.08

^{1/} Excludes cost of expatriate scientists.

Source: Adapted from Oram, 1983, p.6.

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